90-04506/

Energy, Mines and Resources Canada | Energie, Mines et Ressources Canada

CANMET

Canada Centre for Mineral and Energy Technology | Centre canadien de la technologie des minéraux et de l'énergie

ENGINEERING MODIFICATIONS TO CANMET TEST OVENS AND RELATED PILOT PLANT FACILITIES:

PART II: UNATTENDED OPERATION OF OTTAWA TEST OVENS

V. MARWAHA

Coal Resource and Processing Laboratory

April 1980

This document is an unedited interim report prepared primarily for discussion and internal reporting purposes. It does not represent a final expression of the opinion of the Canada Centre for Mineral and Energy Technology (CANMET)

Ce document est un rapport provisoire non-révisé et rédigé principalement pour fin de discussion et de documentation interne. Il ne représente nullement l'expression définitive de l'opinion du Centre canadien de la technologie des minéraux et de l'énergie (CANMET)

ENERGY RESEARCH PROGRAM

ENERGY RESEARCH LABORATORIES

REPORT ERP/ERL 80-40(TR)

5 pp

ENGINEERING MODIFICATIONS TO CANMET TEST OVENS AND RELATED PILOT PLANT FACILITIES

Part II: Unattended Operation of Ottawa Test Ovens

by

V. Marwaha*

SUMMARY

Ottawa test ovens have operated for several years by the coke crew and management under mutually acceptable conditions, referred to as 'sweet heart' agreement. This agreement was necessary as oven 18-70 required continuous manual supervision during night-shift. On December 1979, oven operation under this agreement was discontinued, since oven 18-70 was suitably equiped to operate continuously without any manual supervision for the night shift. This new mode of oven operation generally referred to as 'unattended operation' has now been practised for the last five months, without any breakdowns.

Historical background necessitating the introduction of unattended operation and important aspects of bringing about this change are discussed, in the light of experience gained by other similar research laboratories.

---

*Coal Research Engineer, Coal Resource and Processing Laboratory, Energy Research Laboratories, Canada Centre for Mineral and Energy Technology, Department of Energy, Mines and Resources, Ottawa, Canada.

CONTENTS

	Page
SUMMARY	1
INTRODUCTION	1
CARBONIZATION PROCESS	2
CARBON BUILD-UP AND ITS REMOVAL	3
ESSENTIALS OF UNATTENDED OPERATION	4
Selection of a Carbon Removal System	5
Selection of a Smoke Detector	7
Selection of a Flame Detector	7
High and Low Temperature Alarms	7
Method of Operation	8
CONCLUSIONS AND FUTURE WORK	10
REFERENCES	11

FIGURES

No.		
1.	Carbon removal system installed on oven 18-70	6
2.	Unattended oven operating schedule	9

INTRODUCTION

Canada Centre for Mineral and Energy Technology (CANMET) of the Department of Energy, Mines and Resources (EMR) uses technical scale coke ovens for the evaluation of the properites of coking coals (1-7). It has been the goal of the Ottawa laboratory for several years to run these ovens unattended, during night shift with the intention of:

(i) reducing manpower in the present climate of financial restraint

(ii) improving supervision by eliminating the night shift

(iii) providing more efficient operation

Traditionally CANMET ovens located in Ottawa have operated under a 'sweet heart' agreement between the coke crew and management. An essential feature of this agreement was that two men from coke crew worked for three night shifts per week, each night shift lasting 13h 20 min. This working arrangement was derived for oven no. 18-70 which had to be monitored during each test run for a period of 18h. A major drawback of this agreement, was that if one crew member of the night shift failed to report for duty, the test had to be cancelled for safety reasons resulting in one man sitting idle for the entire night shift.

As activities of CRPL expanded, more efficient operation of these ovens was required, and it became difficult to manage, if there was any absenteeism during the night shift. It was also recognized that the work-load for the night shift was insufficient for two men. If the essential part of their work could be automated, then the night shift could be eliminated.

This task of making the oven operation unattended was entrusted to engineering personnel in CPRL. Essentially it involved:

(a) detailed understanding of carbonization process

(b) a careful analysis of the opeations conducted by night shift personnel, with the possibility of either eliminating or automating them

(c) an assessment of the hazards involved in switching over to unattended operation and

(d) provision of a system to prevent these hazards.

The present report is an attempt to summarize the effort required to bring this long awaited goal to the point of actual operation, and pertains to oven no. 18-70.

CARBONIZATION PROCESS

Carbonization is the destructive distillation of bituminous coal resulting in the formation of coke. It is an exothermic process carried out in slot type ovens in the absence of air. Within a few moments of charging an oven, the coal immediately adjacent to the hot wall begins to soften and decompose. As the process continues, the rate of softening and decomposition increases and there is an active evolution of gases from the plastic mass. The plastic stage is a transient one, resolidification soon sets in, and a layer of coke begins to form at the wall. The plastic zone may be conceived as a vertical layer a few centimeters thick, essentially plane, bounded on one side by coke and on the other by untransformed coal.

The gases released are a mixture of several hydrocarbons (9) known as coke oven gas, which is combustible as well as harmful (8). It passes through a 4 in dia gas off-take pipe and flared. During a typical carbonization run there is a slow deposition of carbon in the gas off-take pipe. The rate of carbon deposition varies over the carbonization cycle, but is generally higher in the first few hours due to carbon carryover from the coal charge. This deposition plugs the gas off-take pipe and thereby prevents the flow of gas. Consequently the gas leaks from several areas around the oven roof and doors without burning. If such a situation exists for a couple of hours, it could result in the accumulation of potentially dangerous levels of a harmful and combustible gas, leading to explosion or fire.

One of the important tasks of the night crew was to clean the gas off-take pipe occasionally to ensure that coke oven gas was flared properly and that there was no build up of unburnt gas to dangerous levels. Cleaning the gas off-take pipe was done manually using a chain, and required continuous supervision. This part of the work conducted by the night crew was critical, and posed a major hurdle in going unattended. The first part of the present work was therefore devoted to a study of these carbon deposits and existing methods to remove them before providing a suitable

alternative. The latter part of the work related to selection of detectors and alarms, and a method of operation to fit in the new framework.

CARBON BUILD-UP AND ITS REMOVAL

Visual examination at the tip of the gas off-take pipe showed a fine sooty carbon, whereas the deposit on the chain appeared to be a sticky material. The structure of this carbon and its mechanism of formation was studied by Zavitz (13), Shemeryankin et al (14), Weiler (15) and Berkowitz (16). Metallographic examination of roof and wall deposits taken from an actual industrial oven, showed that carbon was spherulitic and composed of three different forms which Zavitz (13) termed as modular masses, surrounded by thin laminations of lustrous carbon, with nodules of soft soot like inclusions. Further investigations were carried out by lowering a silica brick in the free space of the industrial oven and collecting the deposits for the 18 hr carbonization period. After one coking cycle, a fragile carbonaceous deposit consisting mainly of tree-like or dendritic growths up to 1/2 in length was present mainly on the downstream side of the brick. It was also found that most of this deposit was formed during the first hour of the coking cycle. Microscopic examination indicated that this deposit was very fine grained. Detailed examination using a scanning electron microscope revealed that the nature of this carbon was sphere-like deposits formed in a gas stream as a very fine mist with droplet dia's ranging from one tenth of a micron to several microns. This mist originated from coal decomposition products, which undergo secondary thermal treatment as they travel through hot coke, oven walls and free space. This resulted in a progressive dehydrogenation and linking up of hydro-aromatic compounds to form condensed aromatic ring structures as shown by Weiler (15). By the time these droplets reached the oven roof and gas off-take pipe they were in a semi-solid condition.

Attempts to mechanize the operation of carbon removal at CANMET consisted of periodic injection of air (10) into the gas off-take pipe. The system did not work and was eventually discarded. Another approach followed was to collect tar (11), instead of flaring the gases, and thereby eliminate the problem of removing carbon in the gas off-take pipe. This attempt did not prove successful and was discarded (12) because

(i) the tar recovery train and its operation became too complicated and its operation very costly.

(ii) it was difficult to simulate commercial conditions producing representative tar samples.

(iii) the tar recovery system demanded substantial changes in the existing oven design.

Communication with other research centres revealed that Republic Steel had developed a 'Rotating Plug' with a 'Rabble Plate', programmed to be lowered into the gas off-take pipe every hour. During the time the pressure peak was due, the plug was programmed not to be lowered. The backpressure was maintained at 0.15± 0.02 in. of water column. Bethlehem Steel was found to have a different system in which the coke oven gas was scrubbed counter-currently with water in two columns packed with coke to separate tar. A flexible hose connection from the gas off-take pipe sensed the oven pressure via a pressure transducer and controlled it through a control valve by adjusting the flow of gas, which was aspirated with live steam to atmosphere. Such a system would require frequent cleaning of the pipes as the tar would condense at several spots. A somewhat similar system was observed by the author at Consolidation Coal Company.

U.S. Steel Research Centre at Monroeville had an altogether different approach evolved after a considerable experimentation. The practice of tar separation and back pressure control via a control valve had been tried and rejected. The present system in practice was based on the fact,

(a) that most of the carbon deposition in the gas off-take pipe occurred in the first two hours of carbonization.

(b) that the back-pressure was a direct function of the temperature at the gas off-take pipe.

The gas off-take pipe was cleaned during the first two hours of the carbonization cycle and then left unattended. The temperature at the gas off-take pipe was maintained at 300-350°C by restricting the flow of gas at the off-take pipe.

ESSENTIALS OF UNATTENDED OPERATION

Technical scale ovens in Ottawa operate continuously to evaluate

new coking coal seams, to conduct research studies pertaining to carbonization and to carry out cost recovery tests for the mining and steel industry. There is a regular oven operation schedule under which 4 to 5 tests are conducted every week. It becomes imperative under these circumstances that any change introduced in upgrading the ovens must be carefully planned, with full knowledge of the process and must take into consideration the possible hazards that might occur if the system fails at any stage.

Unattended operation was finally introduced in the middle of December 79 after succesfully operating the carbon removal system for a period of five months. During this period the detectors/alarms were connected to the computer terminal located in the heating plant control room (of building no. 1), which was continuously monitored.

Selection of a Carbon Removal System

Gas burning and plugging of the off-take pipe was observed over a period of several months. Frequency of plugging and nature of carbon deposits were monitored visually. Discussions were held with crew members and it was decided to devise a simple mechanical scraper to remove the deposits and require little maintenance. Figure 1 shows the arrangement which was developed and put into operation in July, 79. An iron strip 1/8" thick was shaped into a conveyor coil rotating at 3-4 rpm in the gas off-take pipe. The coil conveyed the deposits as well as scrapped them from the walls of the pipe. A chain and sprocket drive was used to avoid any slippage, and to provide more power to the driven coil. The motor and the gear assembly was picked up from the discarded material stored in the old coke oven pilot plant at Booth Street. The motor has a high temperature cut-off and the system has operated extremely well without any breakdowns.

When the oven is charged a black cloud composed of entrained finer coal particles, moisture and yellow gas is released. This gas mixture is flared using propane gas. It is important that this gas mixture be flared instantaneously as it comes out of the off-take pipe. The old method of flaring the gas mixture through an open pipe was discarded, in favour of a power burner, with a thermally protected motor and a spark ignition switch. The performance of this burner has not been very satisfactory and a simple nozzle type burner may be more practical.

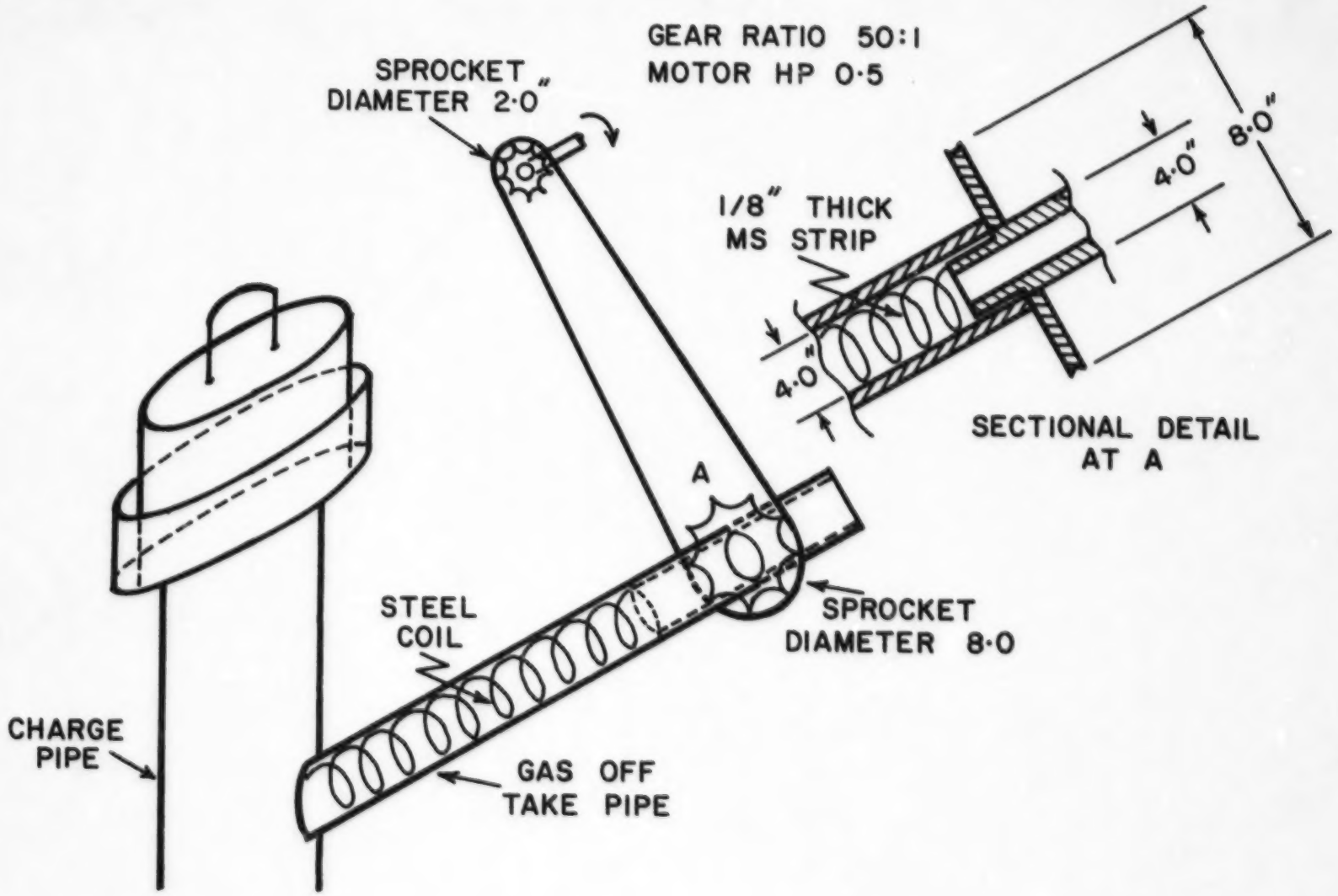

Figure 1. Carbon removal system installed on oven 18-70.

Selection of a Smoke Detector

This was considered necessary to ensure that there was no gas leakage from oven roof and doors, and that the gas was burnt properly. Incomplete or partial flaring would cause smoke. The Pyre-A-Larm model DS-2 supplied by Pyrotronics was selected, which operates on the light-scattering Tyndall principle. A light emitting diode (LED) and a photo-cell are arranged in a labyrinth so that light can only fall onto an opto-electrical transducer when scattered by smoke particles. When a certain threshold is exceeded, a voltage is generated which is amplified by a transistor circuit, initiating the alarm.

It is fitted with an indicator lamp, operates from a 22 V dc source and responds directly to visible smoke concentrations of 1.2% per foot obscuration. It is mounted on an iron stand so that detector head can be swung at any location and at any height above the charge pipe of the oven.

Selection of a Flame Detector

This detector was considered important to ensure continuous flaring of the gas at all times. The Pyre-A-Larm flame detector series C-7037 was slected. This detector is essentially a Geiger-Mueller gas type cathode tube that is designed to detect flame-radiated rays in the extreme low (ultraviolet) end of the radiation spectrum, at a wavelength ranging from 1850 to 2450 A°. Radiation is emitted in small bundles of photons. When a photon of ultraviolet radiation is seen by the detector tube cathode, electrons are drawn to the anode causing a small flow of current through a relay. Under normal operation when the detector sees the flame, the relay is open and activates the controller alarm circuit.

High and Low Temperature Alarms

Oven no. 18-70 operates isothermally at 2050°F. Overheating of this oven could cause melting of the refractory and burning of the electrical components. When the oven has to be shut down it requires a controlled rate of cooling to prevent any excessive stress on the oven walls which are lined with silica bricks. Hence, high and low temperature alarms are both important for this oven.

The oven temperature is controlled by Honeywell supplied single mode proportional controllers named 'Dialotrols'. There are four Dialatrols corresponding to four heating zones in the oven. Each Dialatrol has a built in high and low temperature alarm relay. Whenever the difference between the set temperature of any zone and its actual temperature exceeds 250°F, the alarm relay is actuated. When the alarm relay is actuated for the low temperature side, there is an additional provision of an audible alarm in the pilot plant, to alert the coke crew. The alarm relay can be actuated at any temperature setting by the knobs on the Dialotrols.

Method of Operation

The oven operating schedule is shown in Figure 2. Oven 18-70 is generally charged at 1:30PM and pushed the next day around 10:30 AM, whereas oven 12-71 is charged at 5:30 am and pushed the same day around 3:30 pm. Whenever oven 12-71 is charged, two crew men work from 5:30 am till 1:30 pm, and the rest of the crew works from 8 am to 4 pm. Oven operation is unattended from 4 pm to 8 am the following day. During this period the controls and alarm signals are hooked up to the heating plant control room, which has at least one man on duty around the clock. Any alarm signal from the coke ovens is then transmitted to the heating plant control room operator, who pages the technician on duty if required.

During the months of July and August the heating plant is shut down for six weeks. Re-adjustment of oven operating schedule during this period is therefore required since signals from oven 18-70 cannot be communicated. Some of the possible arrangements are as follows:

(i) signals from oven 18-70 be hooked to an answering service through Bell Canada lines so that oven operation becomes completely independent of heating plant operation.

(ii) during the six week period when heating plant is shut down, oven 12-71 only should be run. Three weeks prior to and three weeks preceeding the closing of heating plant, oven 18-70 only should be operated.

(iii) the night shift be re-introduced temporarily for the period the heating plant is closed.

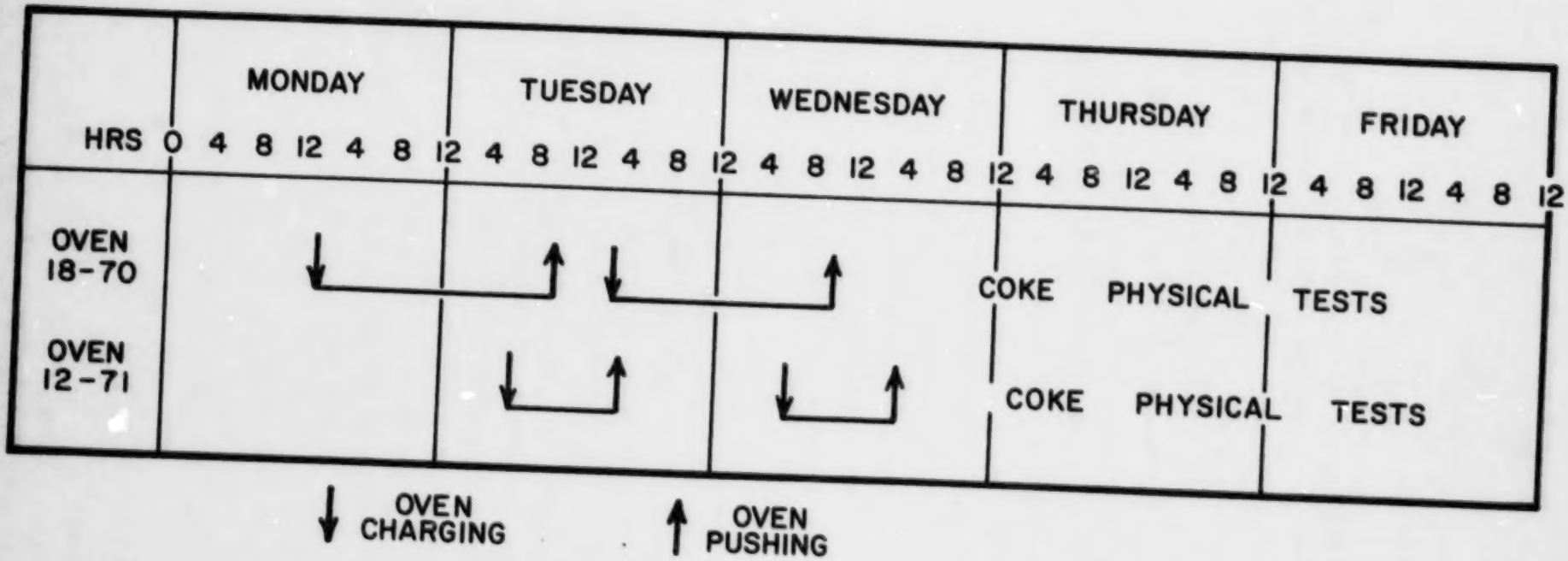

Figure 2. Unattended oven operating schedule.

CONCLUSIONS AND FUTURE WORK

Ottawa ovens are now being run unattended overnight since mid December 79. During this period of four months, the carbon removal system and the alarms have worked effectively giving fast response to the computer located in the heating plant control room. The carbon removal system has also been fixed on oven 12-71 to further reduce monitoring. Traditionally accepted 'sweet heart' agreement has been discontinued, and the available manpower is now utilized more effectively during the day shift.

However, some important considerations that surfaced during the course of this work and in the light of experience gained at similar research organizations, are as follows:

(i) back pressure control is an important parameter in carbonization tests and it is neither controlled nor measured in Ottawa test ovens. The practice at U.S. Steel Research Centre appears to be simple yet accurate, wherein gas off-take temperatures are related to the back pressure. This relationship should be investigated and brought into practice at Ottawa.

(ii) operating schedule of oven 18-70 is now tied into the operation of the heating plant, which is closed for six weeks every year. It might be worthwhile in the long run to eliminate this dependency by connecting instead the alarm signals to an answering service.

(iii) another area of further manpower reduction is the coke screening operation. Smaller size coke less than 2 in. could be mechanically sieved. Also, for the determination of hardness and stability (17), the screening of the tumbled coke can be mechanized.

(iv) carbon deposition in the gas off-take pipe should be further investigated. Zavitz (13) experience of deposition within first hour of carbonization agrees well with the practice at the U.S. Steel Research Centre. However, CANMET's experience in this regard has been somewhat different.

REFERENCES

1. Botham, J.C., Reeve, D.A., Walsh, J.H. and Misener, D.C. "EMR facilities in Western Canada for the evaluation of canadian coking coals"; Proceedings of the 25th Canadian Conference on Coal held at Victoria, B.C.; 85-96; Sept. 1973.

2. Haanel, B.F. and Strong, R.A. "Review of investigation on coals and other fules of Western Canada"; CIM Trans; vol. XXXIX; 1936.

3. Haanel, B.F. "Fuel investigations and research in Canada"; Second World Power Conference; June 16-25, 1930; Berlin, Germany.

4. Haanel, B.F. and Gilmore, R.E. "Investigation of canadian coals including their testing classification and utilization"; Engineering Institute of Canada, Montreal Meeting, June 1937.

5. Ignatieff, A., Botham, J.C. and Walsh, J.H. "Canadian coal in ferrous metallurgy"; Blast Furnace, Coke Oven and Raw Materials Proc; AIME; vol. 18; 132-152; 1959.

6. Walsh, J.H., Botham, J.C. and Montgomery, E.W. "A future for Western metallurgical coals"; Proc. of 21st Canadian Conference on Coal; Sept. 1969; Calgary, Alberta; 84-96.

7. Botham, J.C. and Montgomery, E.W. "Some recent observations in experimental cokemaking"; Proc. of Ironmaking Conference, AIME; vol. 28; 124-144; 1970.

8. "NIOSH/OSHA pocket guide to chemical hazards"; Published jointly by US Department of Health, Education and Welfare and US Department of Labour, Publication No. 78-210; September 1978.

9. McGannon, H.E. "The making, shaping and treating of steel"; Published by U.S. Steel Corporation; 89-91; August 1964.

10. Canadian Carbonization Research Association, 18th Technical Committee Meeting; p. 7; May 16, 1968.

11. Canadian Carbonization Research Association, 73rd Technical Committee Meeting; Appendix 7; November 23, 1978.

12. Canadian Carbonization Research Association, 71st Technical Committee Meeting; p. 5; 1978.

13. Zavitz, R.C. "The role of spherulitic carbon in coke oven roof deposits"; Ironmaking Proc. AIME; vol. 28; 268-277; 1969.

14. Shemeryankin, V.B. et al; "The formation and properties of carbon deposits in coke ovens"; Coke and Chemistry USSR; vol. 5; 15-19; 1964.

15. Weiler, J.F. "Various aspects of quinoline insoluble material in tar"; Blast Furnace and Steel Plant; 238-243; March 1967.

16. Berkowitz, N. "The coal-carbon transformation: basic mechanisms"; Contribution No. 365; Research Council of Alberta; Edmonton, Alberta, Canada.

17. "Standard method of tumbler test for coke"; ASTM method; D3402-76.